

Energy and Climate

Brian Chase - Fermilab

Saturday Morning Physics

ENERGY BASICS

- What is energy?
 - mass and energy can convert back and forth
 - the ability to do work

$$E_r = \sqrt{(m_0 c^2)^2 + (pc)^2}$$

SI unit is the Joule

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 - 2) Elastic potential energy
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 - Etc.

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- What is the energy content of
 - 1) A gram of chocolate?
 - 2) A gram of steak?
 - 3) A gram of coal?
 - 4) A gram of gasoline?
 - 5) A gram of uranium?
 - 6) A gram of antimatter?

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 - Etc.
- What is the energy content of
 - 1) A gram of chocolate?
 - 2) A gram of steak?
 - 3) A gram of coal?
 - 4) A gram of gasoline? 50 kJ
 - 5) A gram of uranium?
 - 6) A gram of antimatter?

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- What is energy?
- Ways to store energy:
 - 1) Gravitational potential energy
 - 2) Elastic potential energy
 - 3) Chemical potential energy
 - 4) Nuclear potential energy
 - Etc.
- What is the energy content of
 - 1) A gram of chocolate? 15-20 kJ
 - 2) A gram of steak? 15-20 kJ
 - 3) A gram of coal? 40 kJ
 - 4) A gram of gasoline? 50 kJ
 - 5) A gram of uranium? 10^8 kJ
 - 6) A gram of antimatter? 10^{11} kJ

POWER

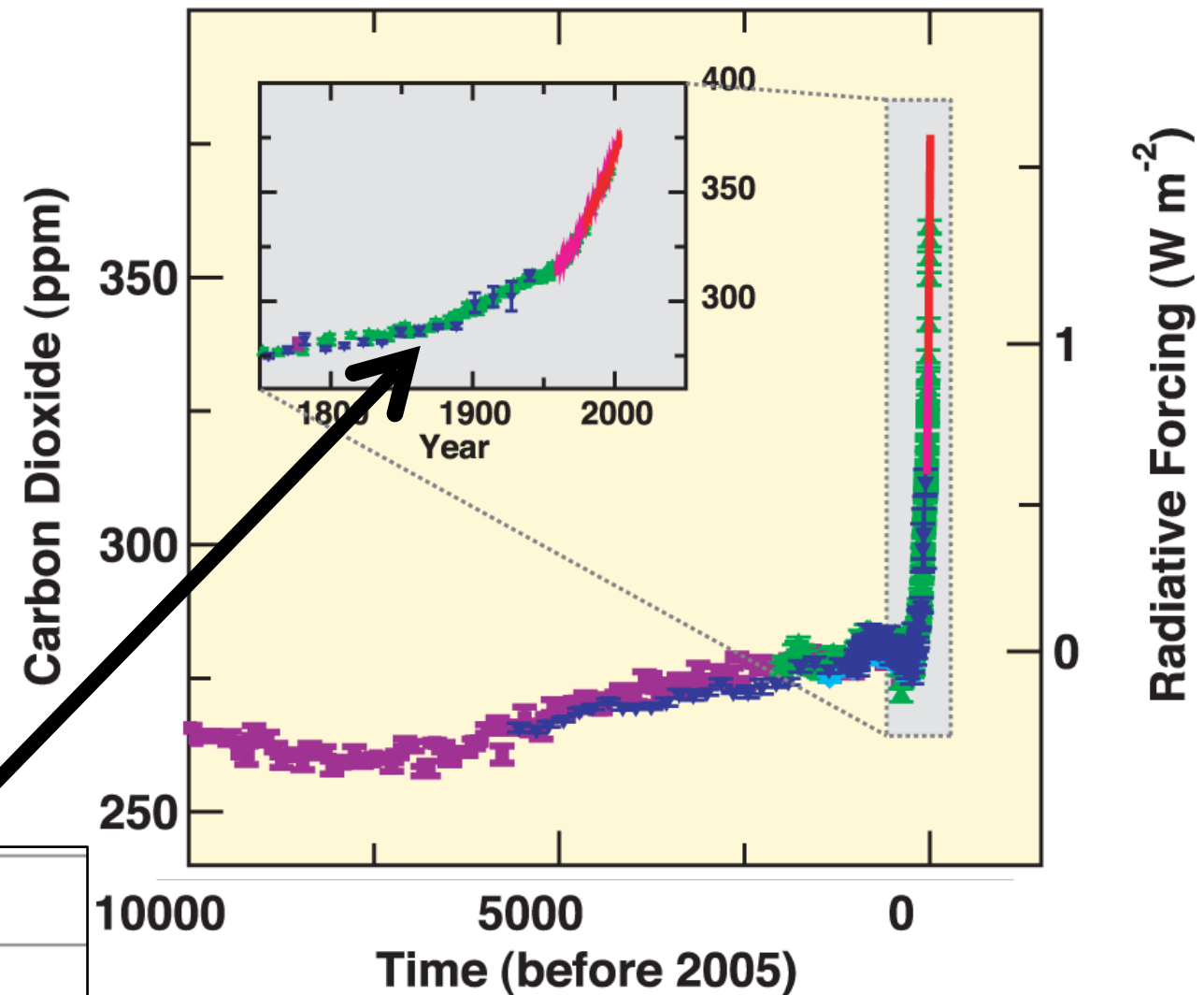
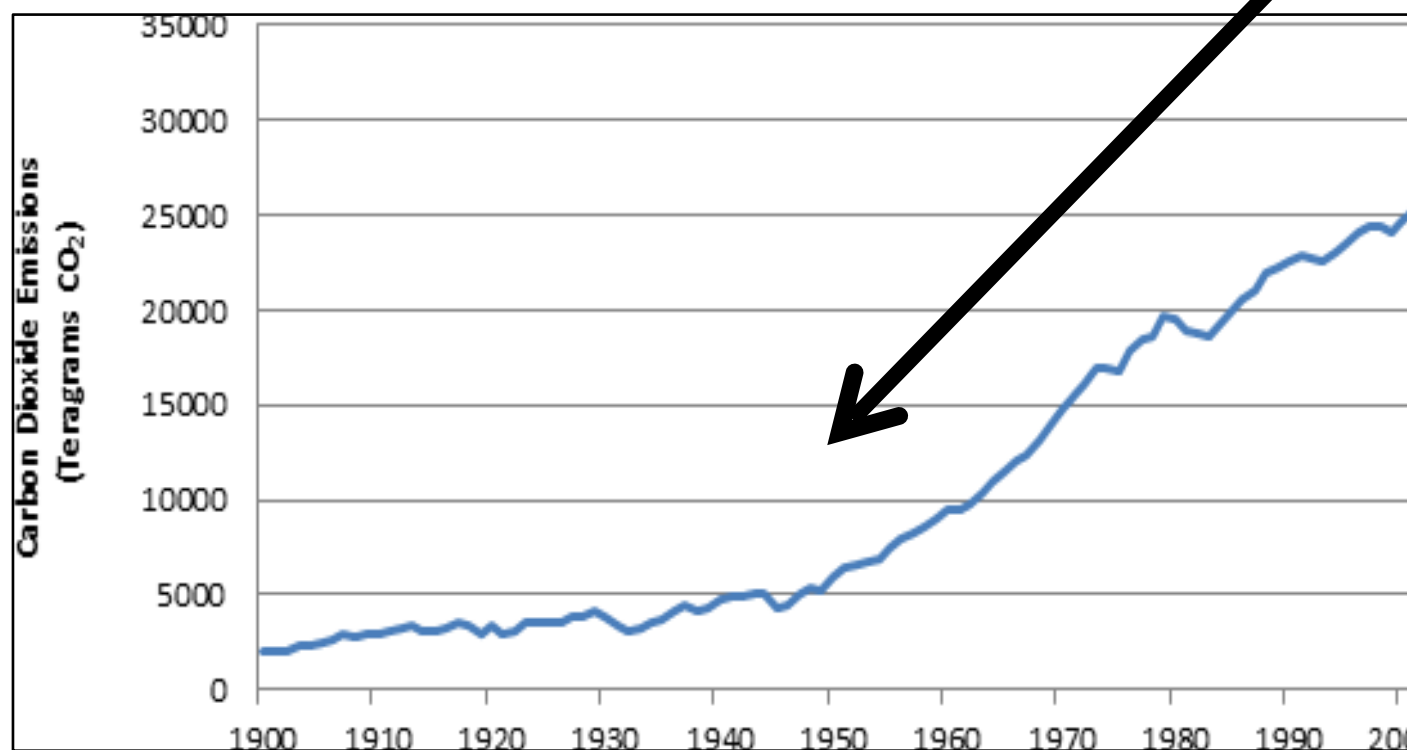
- Power is the rate of doing work. It is the amount of energy consumed per unit time.
- Units
 - Watt = J/sec
 - Horsepower = 746W

Energy and Society

- Fossil fuel enabled the population growth in the last two hundred years and may lead to population decline in the next two hundred years
- Our natural energy budget is about 2.4 kWh per day or 8,600,000 joules from the food we eat while now we use 100 to 200 times that from other sources
- Is our increased use of power natural? Is it healthy?
- Could using less make us happier?

The Connection Between Climate and Human Activity

- The increase in CO₂ and other greenhouse gases is a recent phenomena, coincident with the explosion fossil fuel use and population growth



There is only **one** planet in our reach that life, over billions of years, has terraformed into a place where we can **live**.

Our relationship with the earth is not abstract - it is deeply personal

Sorry, we don't have warp drives



Seven generation sustainability



Page issues

Seven generation stewardship is a concept that urges the current generation of [humans](#) to live and work for the benefit of the seventh generation into the future.^{[[citation needed](#)]} It originated^{[[citation needed](#)]} with the [Iroquois](#) - Great Law of the Iroquois - which holds appropriate to think seven generations ahead (about 140 years into the future) and decide whether the decisions they make today would benefit their children seven generations into the future. It is frequently associated with the modern, popular concept of environmental stewardship or 'sustainability' but it is much broader in context (see the quotation below relative to "in ALL your deliberations ...").

"In every deliberation, we must consider the impact on the seventh generation... even if it requires having skin as thick as the bark of a pine." This is an often repeated saying, and most who use it claim that it comes from [“The Constitution of the Iroquois Nations: The Great Binding Law.”](#) [↗](#)

In fact, the original language is as follows: "In all of your deliberations in the Confederate Council, in your efforts at law making, in all your official acts, self-interest shall be cast into oblivion. Cast not over your shoulder behind you the warnings of the nephews and nieces should they chide you for any error or wrong you may do, but return to the way of the Great Law which is just and right. Look and listen for the welfare of the whole people and have always in view not only the past and present but also the coming generations, even those whose faces are yet beneath the surface of the ground – the unborn of the future Nation."

[Oren Lyons](#), Chief of the [Onondaga](#) Nation, writes: "We are looking ahead, as is one of the first mandates given us as chiefs, to make sure and to make every decision that we make relate to the welfare and well-being of the seventh generation to come. ... What about the seventh generation? Where are you taking them? What will they have?" ^[1]

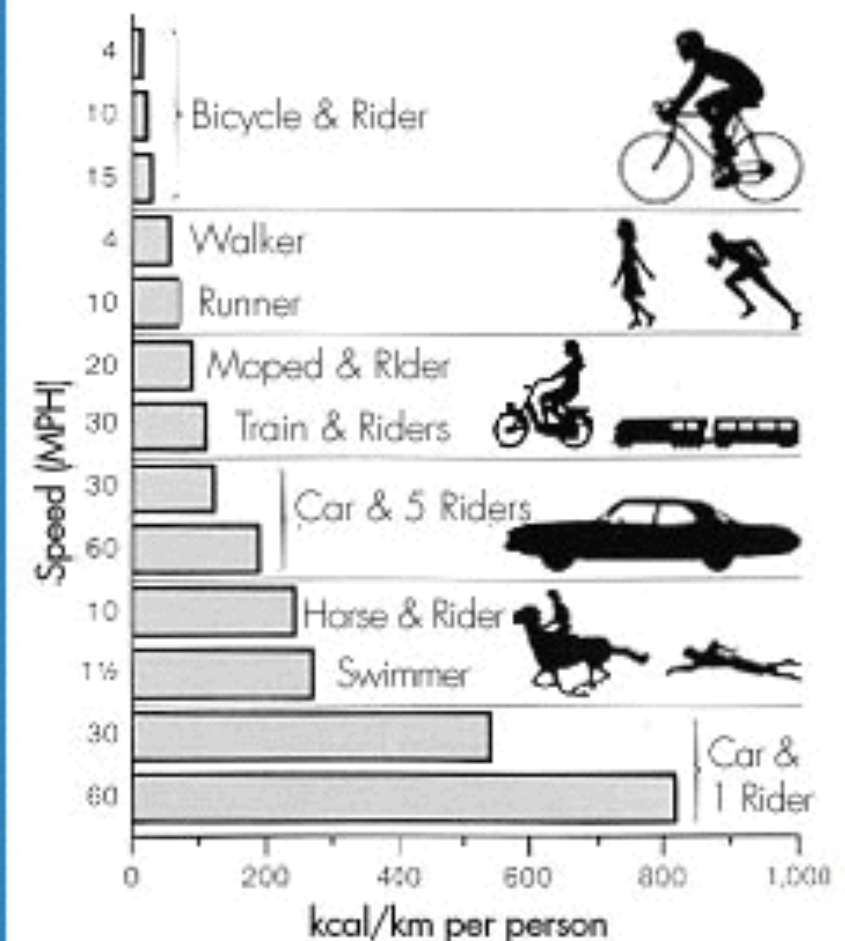
Seven generation sustainability

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What social value do we give to energy?

- Hyper efficient vehicles use 0.84 Whr/km-person
- Bicycles are the most efficient practical transportation
- Transportation only uses as much energy as we are willing to apply to it.
- We pay more for bottled water than we do for gas

1 kilocalorie/hour = 1.16222222 watts



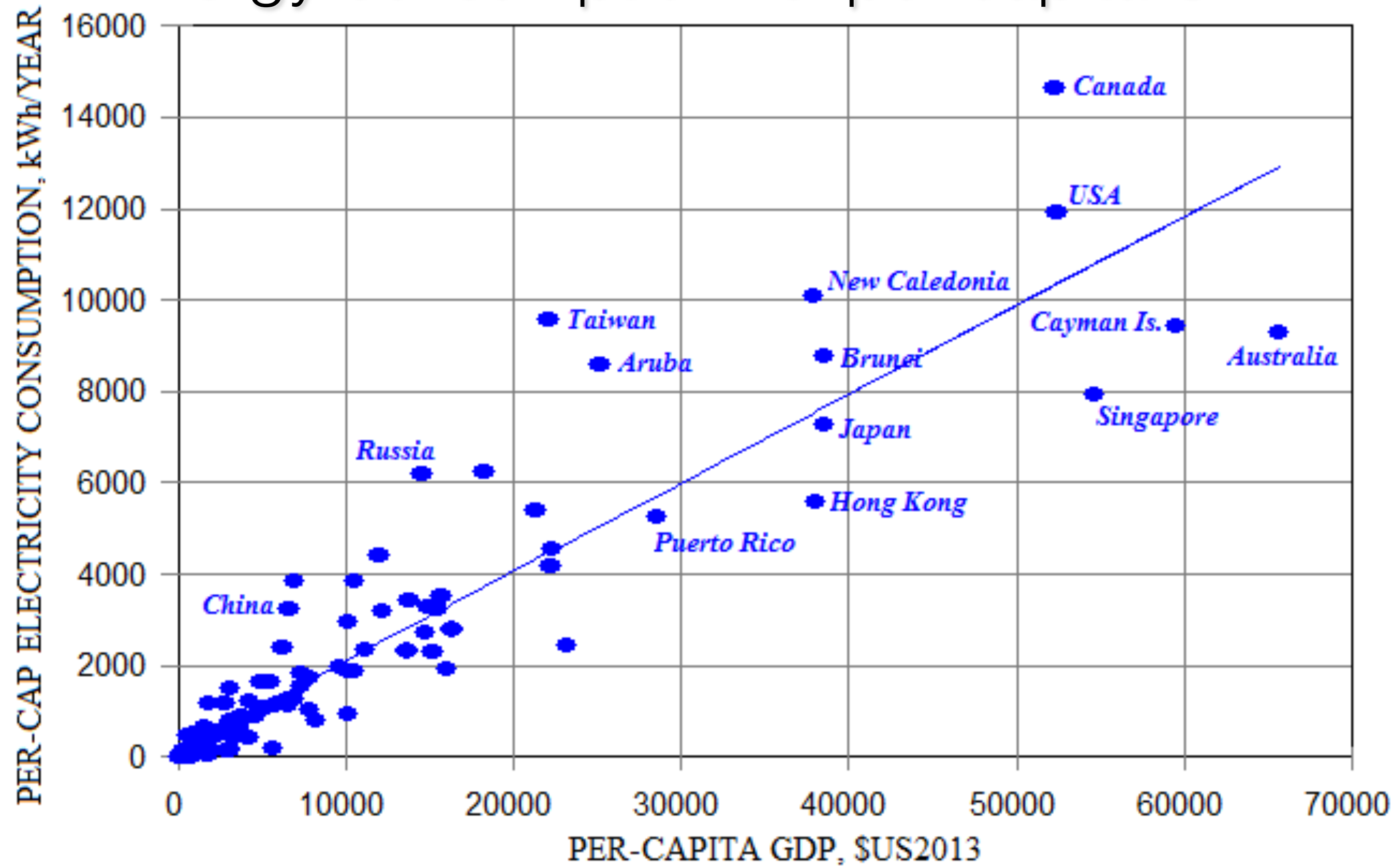
Affluent people on average use more energy

What are the reasons?

- Mercedes-Benz G550
- 13.5 mpg or 1775 Wh / km

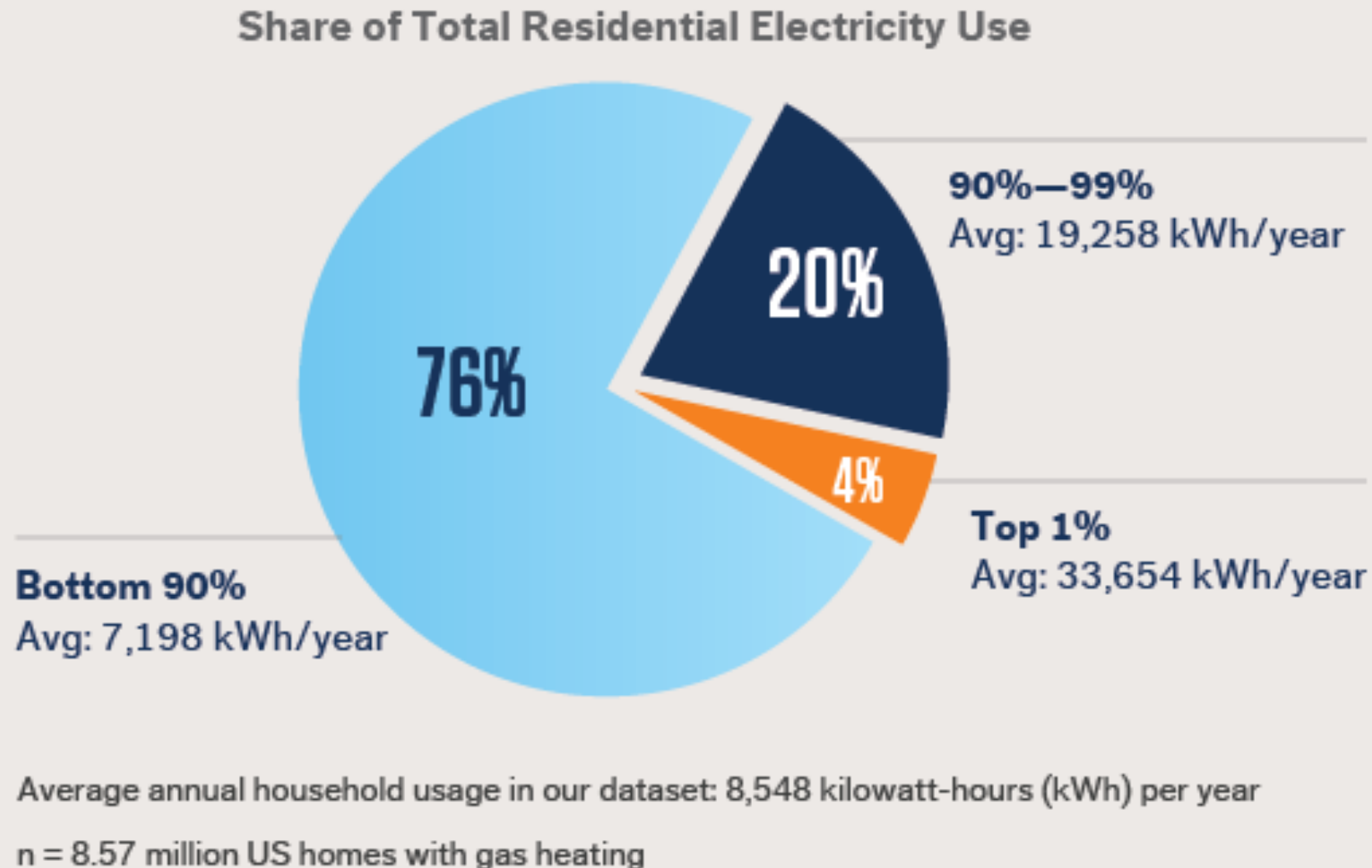


Energy consumption vs. per-capita GDP



The **top 1% of home electricity users** consume **4% of the nation's total residential electricity.**

That means for every unit of electricity the average home consumes, the top 1% of homes are consuming four units.



<https://blog.opower.com/2013/03/americas-energy-distribution-the-top-1-of-homes-consume-4-times-more-electricity-than-average-and-why-it-matters/>



North and South Korea

Political decisions determine energy use

There is no doubt
that energy policy
has become
politicized



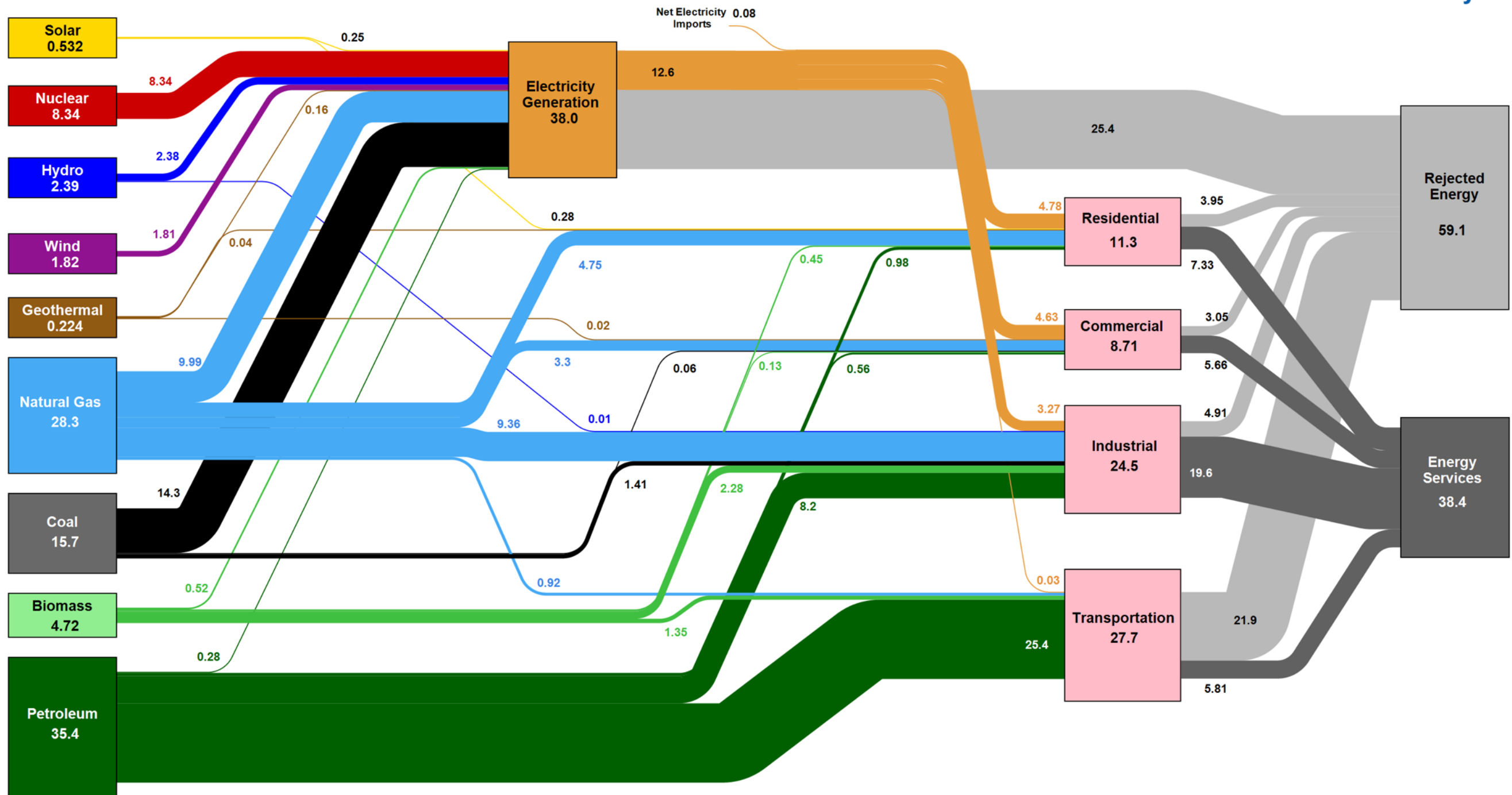
**"You want jobs in the U.S.?
Build wind turbines and
solar panels. Get some
geothermal, some tidal
energy, and we could power
the entire U.S. right now."**

- Bill Nye, CEO of the Planetary Society

Comment Yes & Share If You Agree!



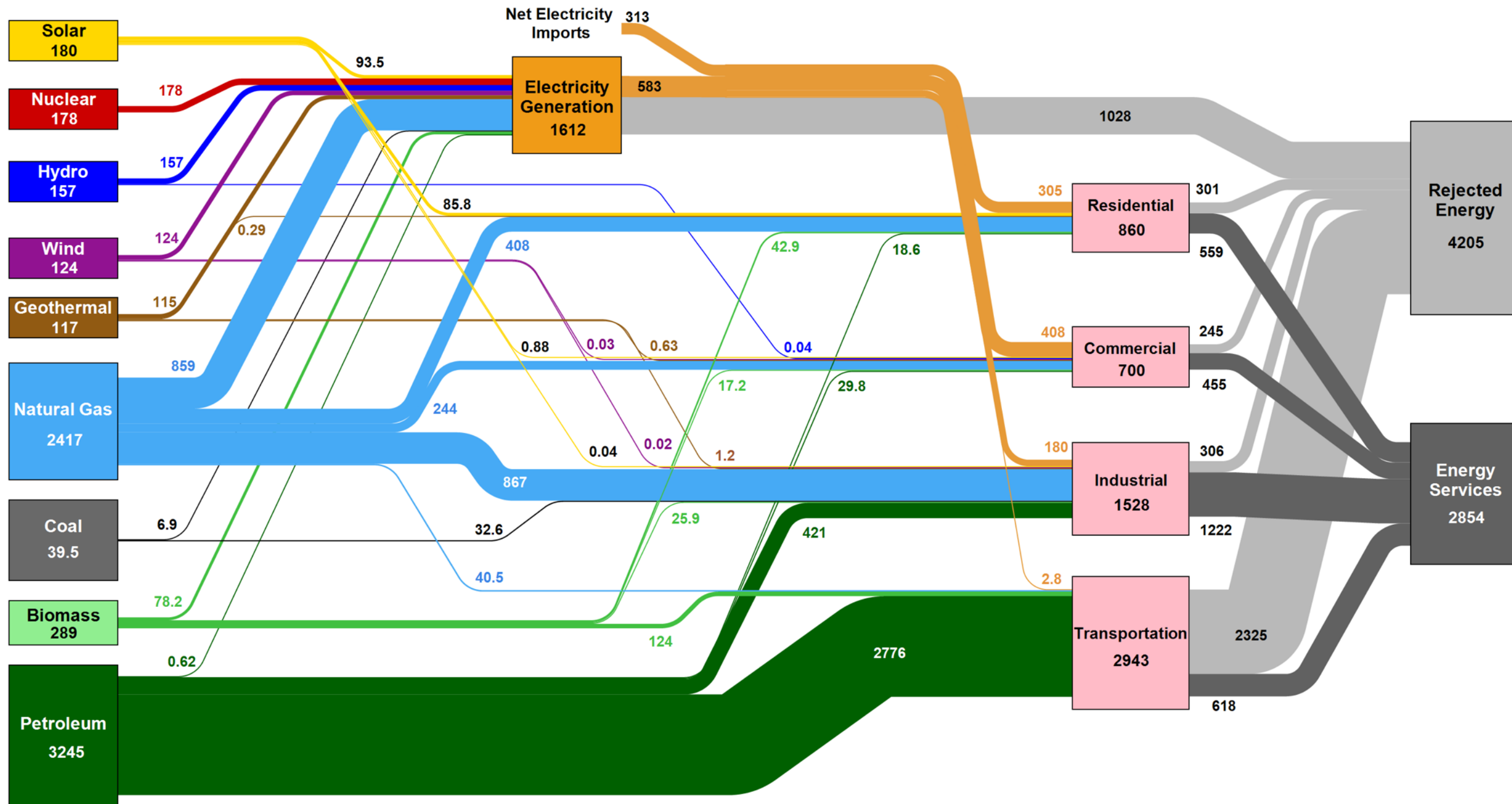
Estimated U.S. Energy Consumption in 2015: 97.5 Quads



Source: LLNL March, 2016. Data is based on DOE/EIA MER (2015). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

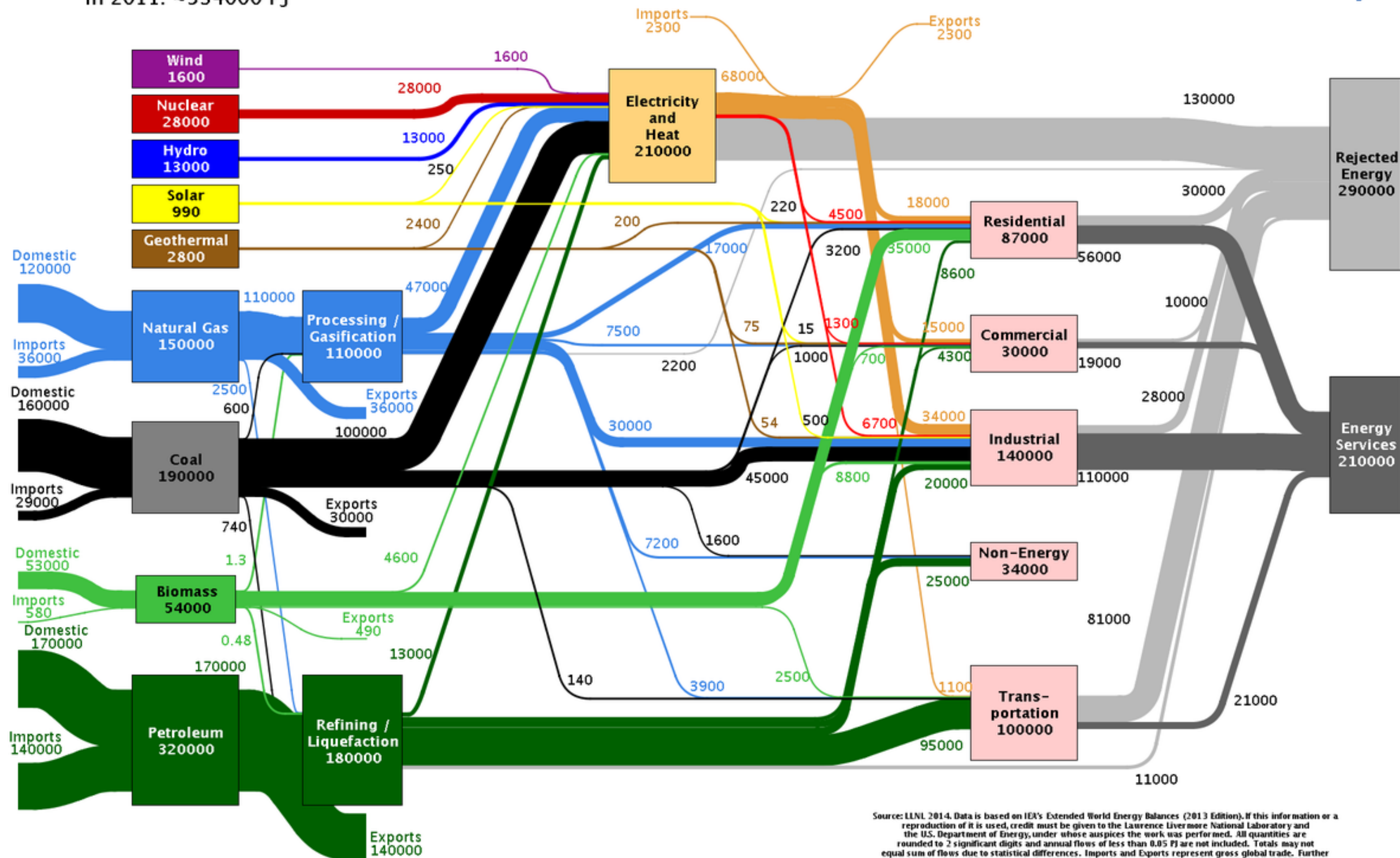
1 QUAD= 1.055 EJ (exajoules)

California Energy Consumption in 2014: ~ 7059 Trillion BTU



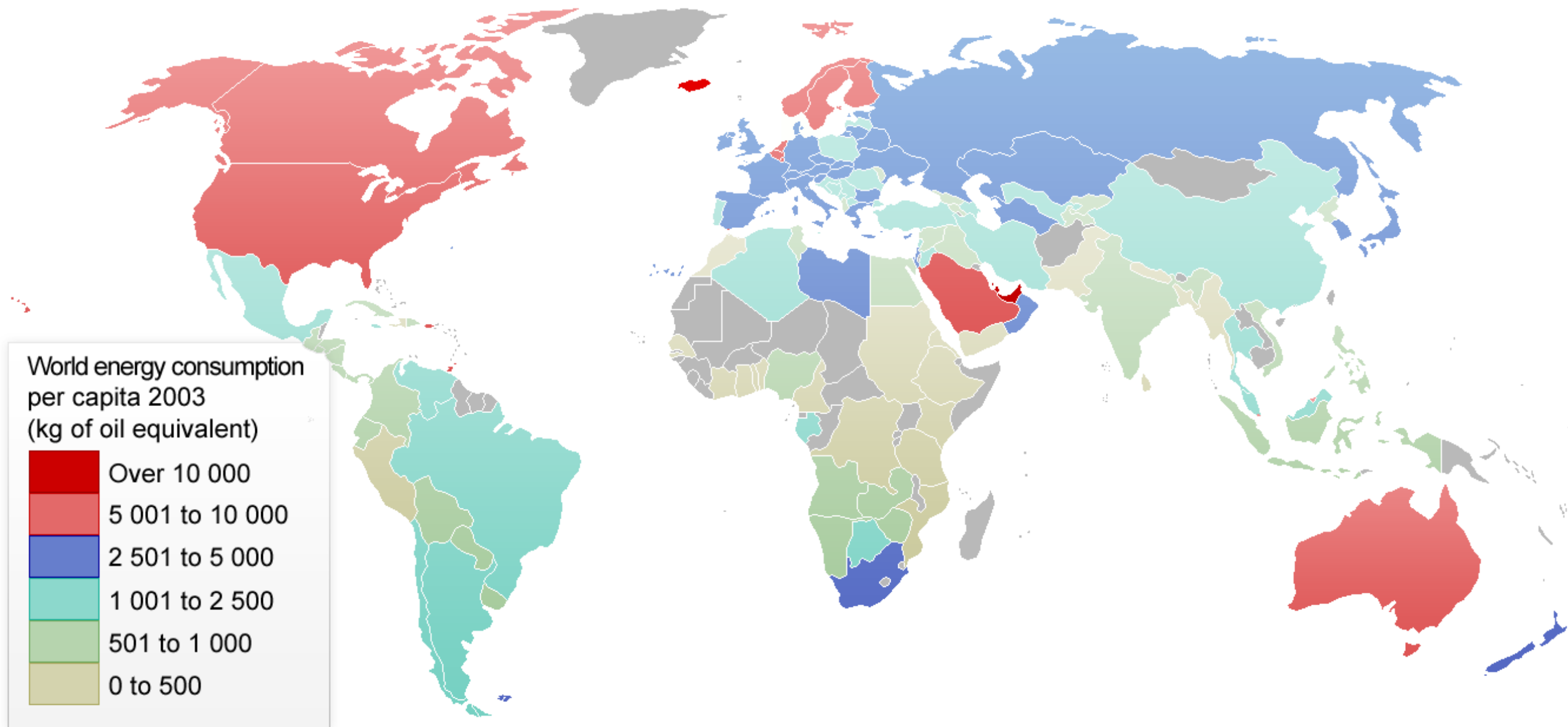
Source: LLNL July, 2016. Data is based on DOE/EIA SEDS (2014). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

World Energy Flow in 2011: ~534000 PJ



Source: LLNL 2014. Data is based on IEA's Extended World Energy Balances (2013 Edition). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the U.S. Department of Energy, under whose auspices the work was performed. All quantities are rounded to 2 significant digits and annual flows of less than 0.05 PJ are not included. Totals may not equal sum of flows due to statistical differences. Imports and Exports represent gross global trade. Further detail on how all flows are calculated can be found at <http://flowcharts.llnl.gov>. LLNL-MI-410527.

World energy consumption



World Views

How do some other countries with high standards of living use less energy than us?

- A lot has to do with national psyche
 - What they collectively value
 - What is their history with energy



Denmark

Other countries are going with renewables

- China kills plans for 85 coal plants and commits \$361 billion for renewables by 2020
- China's renewable energy projects are not only an investment in the future of the Earth, but also in the nation's economy. The NEA estimates the investments will create over 13 million jobs in the energy sector over the upcoming five-year period, which is likely to far surpass the number of jobs eliminated as the country shifts away from its heavy reliance on coal. While China had previously committed to tripling its solar power capacity by 2020, it now looks as though the country is positioned to boost current production by five times.

What can one person do?

- Educate yourself and then teach others
- Change your personal lifestyle and you will affect those around you
- Become politically active locally and nationally





Nega-watts - the cleanest and cheapest power is the power you don't use



What is Realtime Pricing?

- It is part of the smart grid/meter technology intended to level electrical grid loads
- A smart meter replaces the standard meter and records electrical use with short granularity (30 minutes for ComEd)
- The customer is charged the wholesale rate by the hour plus delivery charges plus a charge based on use during two peak load periods
- This motivates customers to reduce use during peak load periods thus reducing peak generation requirements

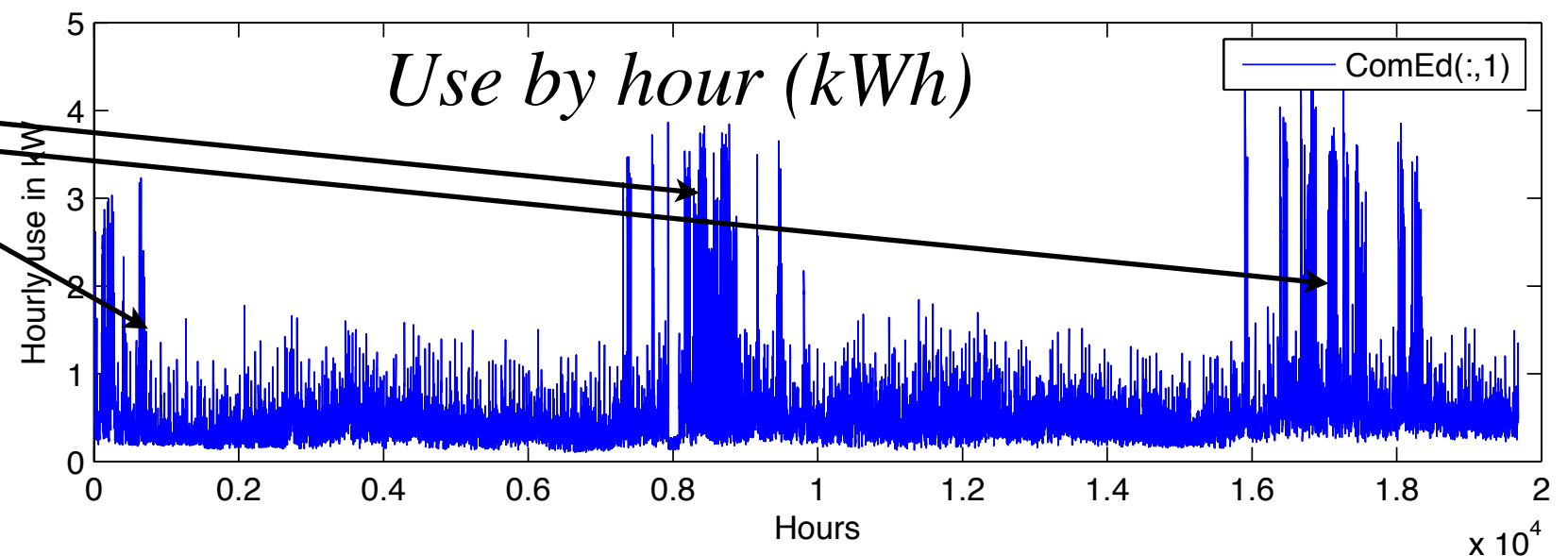
My Home Energy Use with RTP

Realtime Pricing Aug. 2010 - Oct . 2012

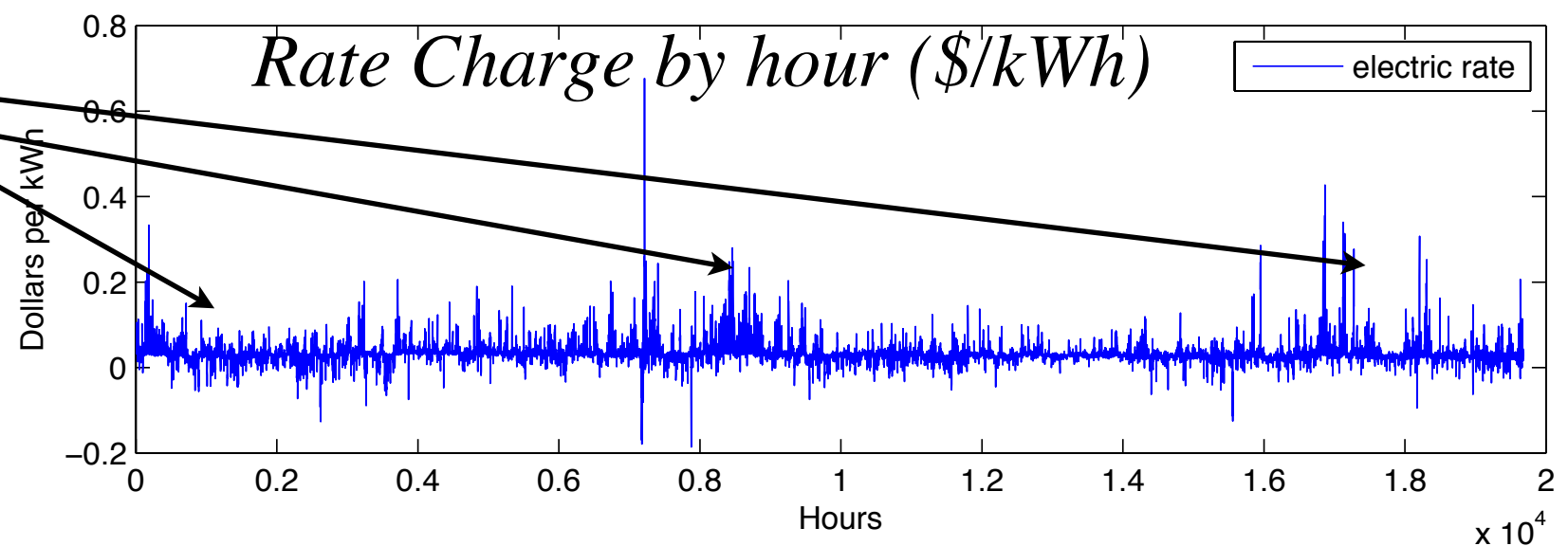
- Average energy used: 0.543 kW
 - Peak use: 4.42kW
- Average wholesale rate over study: \$0.0337/kWh
 - Peak rate:\$0.67/kWh, Minimum rate: **\$-0.185 /kWh**
- Average wholesale rate paid over the study period: \$0.0365/kWh
 - this rate is a little higher than the average because of higher than average energy use during peak rate times (air conditioning)
- Average retail rate paid over study: \$0.0565/kWh - includes 2 cent/kWh delivery charge(wheeling)
 - Average monthly rate : \$22.42 + tax, **capacity charges**, and other small charges.

2+ Years of Home Energy Data

Peak energy use is dominated by air conditioning



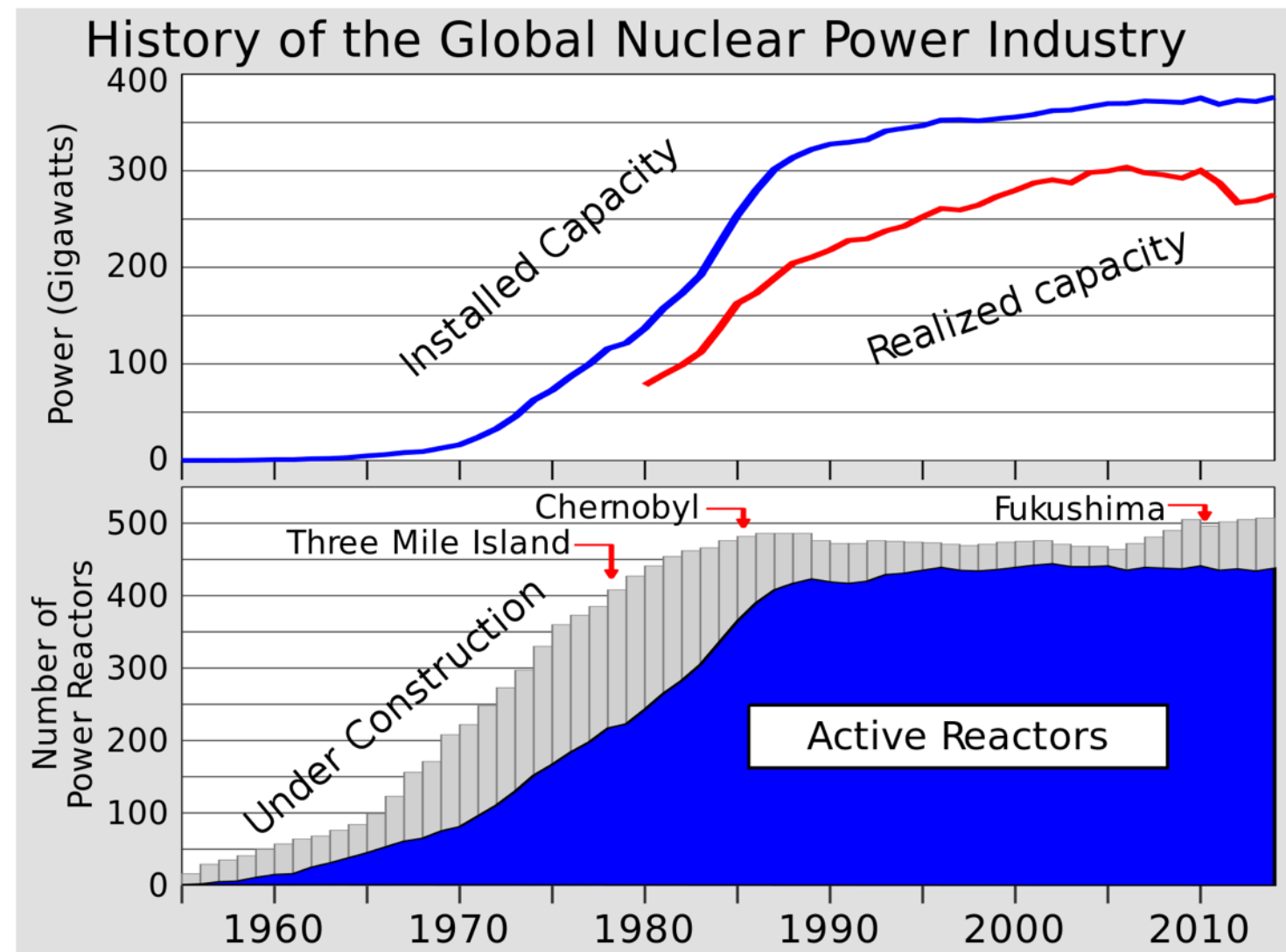
Peak energy rate driven by air conditioning



The trick is to reduce use during high rates

Five reasons to question the nuclear power solution

- The nuclear industry claims that major accidents can only happen on the order of millions years of operation. Yet we have had:
- Three Mile Island, Chernobyl and Fukushima Daichi units 1,2,3



Chernobyl Disaster 1986

- 350,000 people resettled
- 1000 sq mi exclusion zone
- Wide estimates on cancer rates

Location	Radiation (roentgens per hour)	Sieverts per hour (SI Unit)
Vicinity of the reactor core	30,000	300
Fuel fragments	15,000–20,000	150–200
Debris heap at the place of circulation pumps	10,000	100
Debris near the electrolyzers	5,000–15,000	50–150
Water in the Level +25 feedwater room	5,000	50
Level 0 of the turbine hall	500–15,000	5–150
Area of the affected unit	1,000–1,500	10–15
Water in Room 712	1,000	10
Control room	3–5	0.03–0.05
Hydropower Installation	30	0.3
Nearby concrete mixing unit	10–15	0.10–0.15



By Soviet Authorities, Fair use, <https://en.wikipedia.org/w/index.php?curid=4866476>

Small scale nuclear power has intrinsic safety features
It is still more expensive than other options but may play a role

NUSCALE POWER MODULE™

NATURAL CIRCULATION OF REACTOR COOLANT FLOW

CONDUCTION

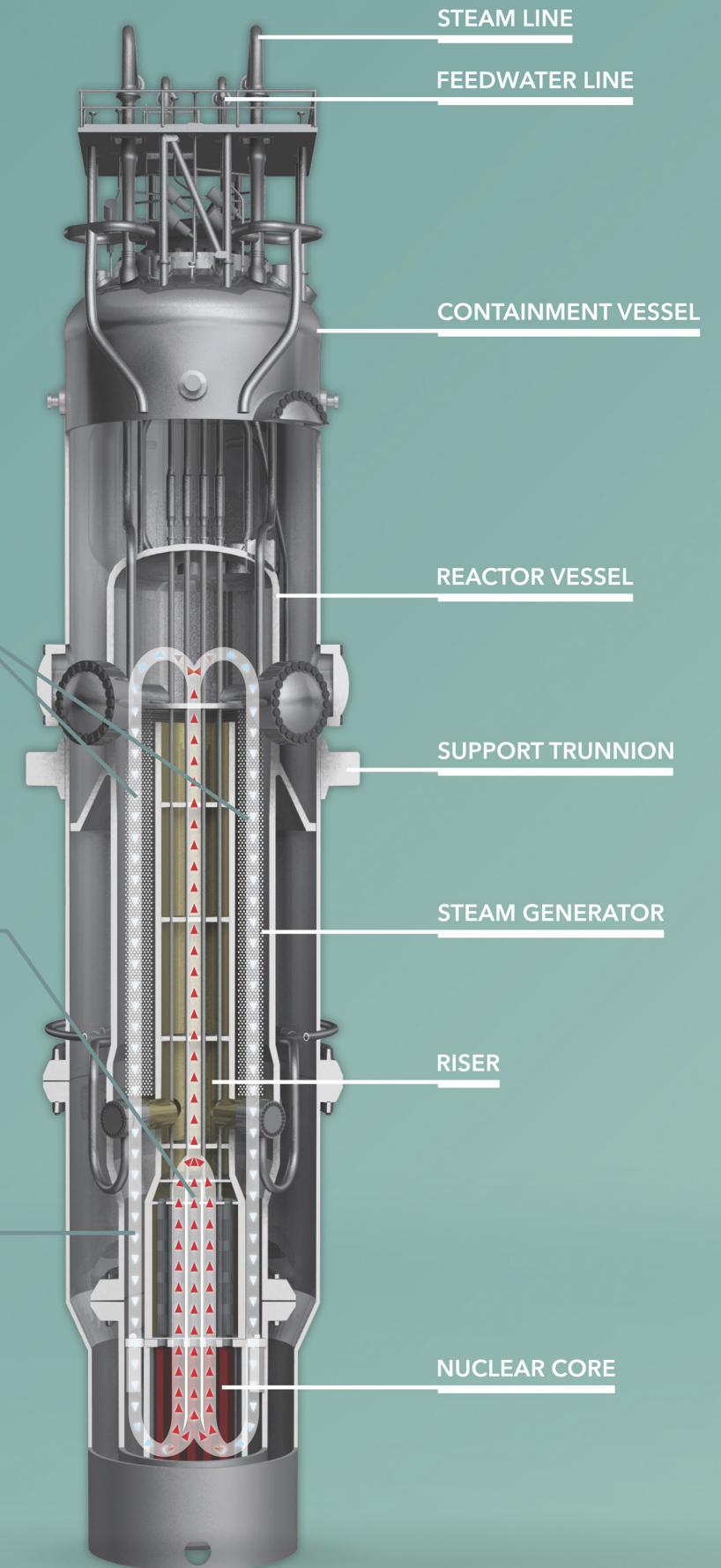
Heat is transferred from the primary coolant through the walls of the tubes in the steam generator, heating the water (secondary coolant) inside them to turn it to steam.

CONVECTION

Energy from nuclear reaction heats the primary reactor coolant causing it to rise by convection and natural buoyancy through the riser, much like a chimney effect.

GRAVITY

Colder (denser) primary coolant "falls" to bottom of reactor pressure vessel, cycle continues.





Big Wind

WIND DEPLOYMENT & COST



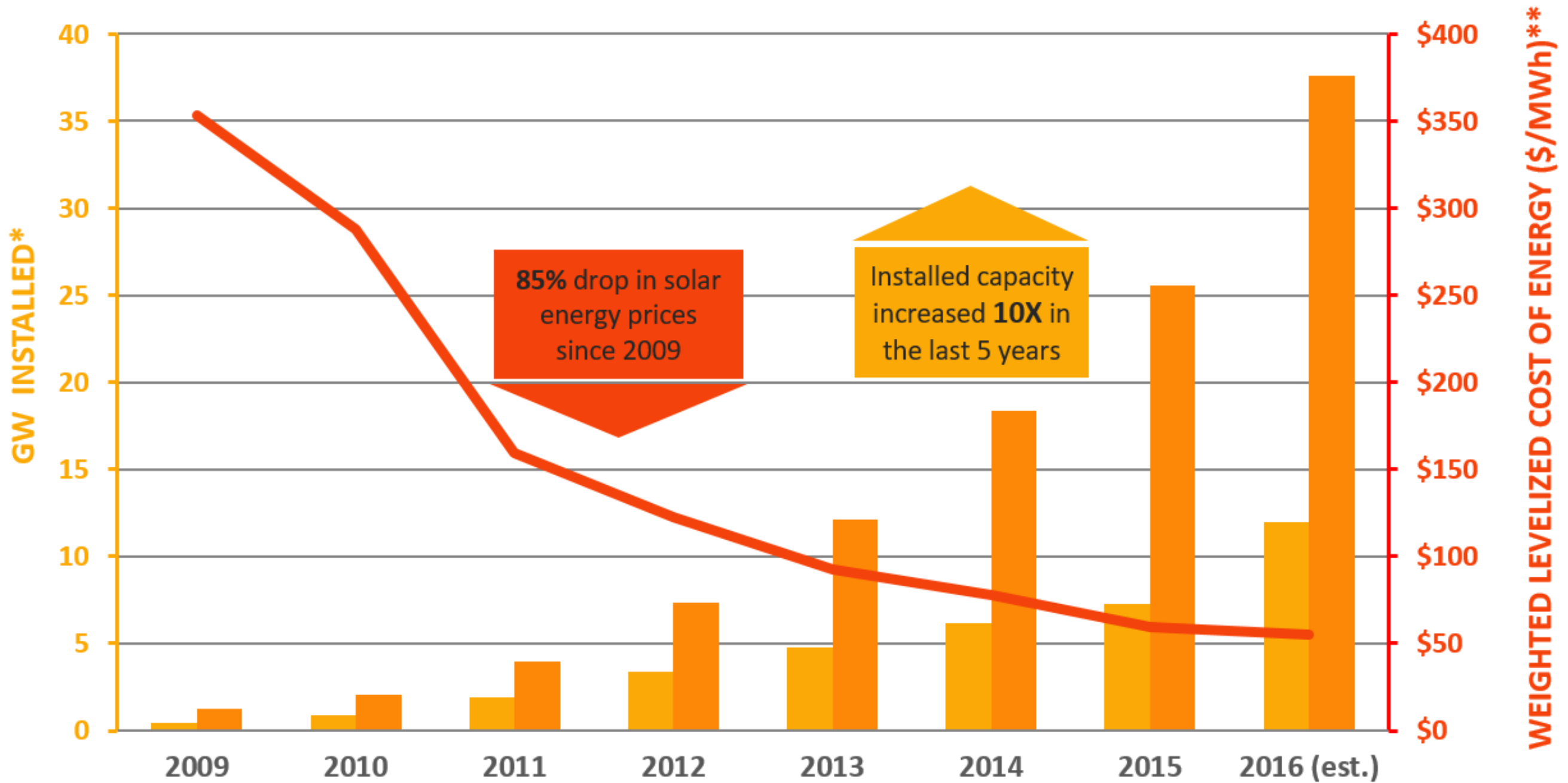
*Annual & Cumulative Capacity - American Wind Energy Association 2016 Q3 Market Report

**LCOE - Lazard's Levelized Cost of Energy Analysis v. 5-10, avg. of high/low figures



Big Solar

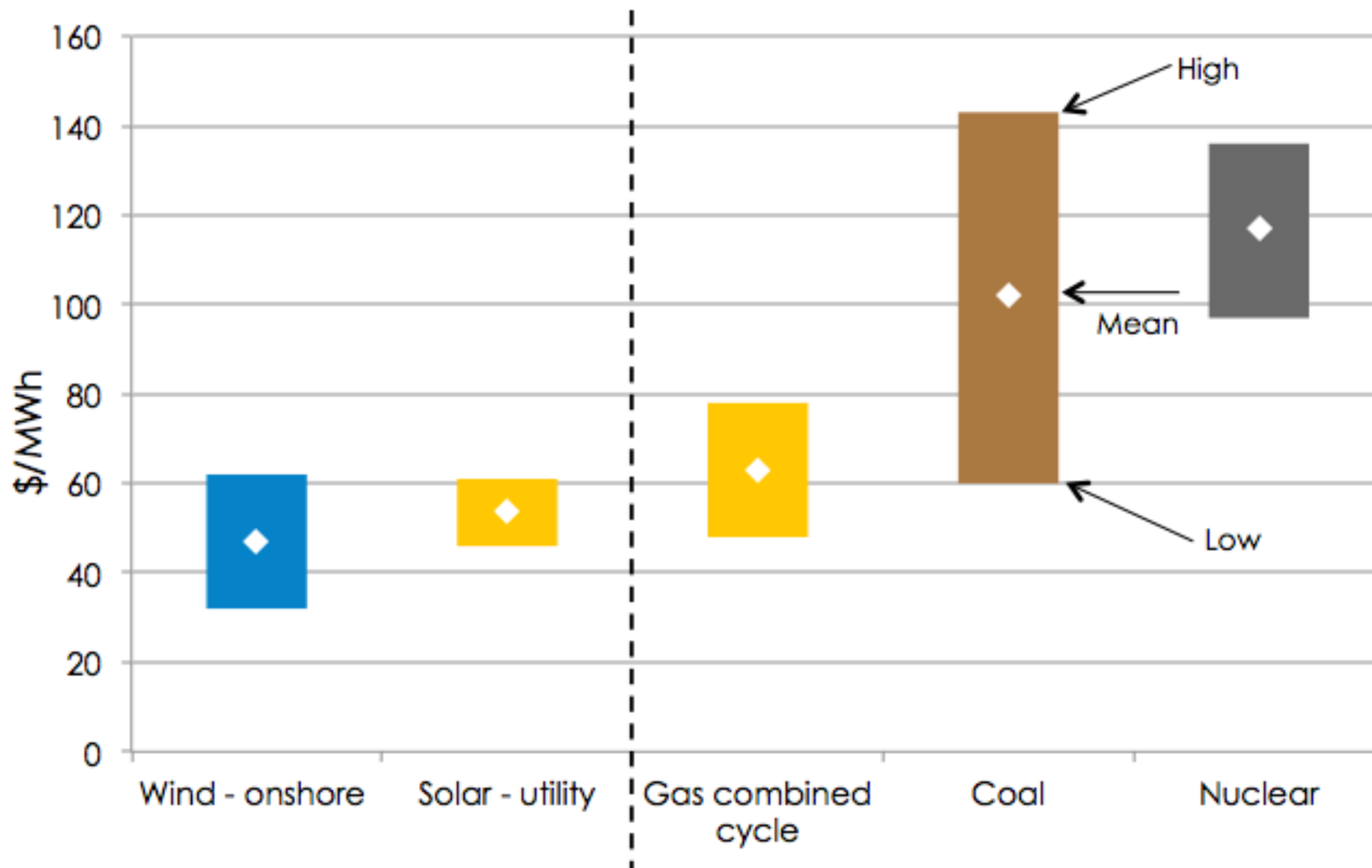
SOLAR COST & DEPLOYMENT



*Capacity - GTM/SEIA Solar Market Insight Report 2016 Q3

**LCOE - Lazard's Levelized Cost of Energy Analysis v. 5-10, technology-weighted avg. of high/low ranges

Levelized Cost of Energy



*Data from Lazard's Levelized Cost of Energy Analysis, Version 10 (Dec 2016).

Fast track to exponential reduction in CO2 production

- **In parallel:**

- Set aggressive short term goals
- Tax carbon (Some republicans are now proposing this)
- Raise mileage standards for cars and efficiency standards for other technology
- Increases funding for research
- Use California approach to energy pricing where the price goes up the more you use
- Incentives for renewables
- Smart grids and smart metering with real time pricing
- Open up access to the grid for small energy producers

Conclusions

- Our current energy use is unsustainable and is damaging life on our planet. This is self destructive behavior
- Wind and solar are cost competitive now
- It will take commitment to change our energy sources and use but the cost will be small compared to doing nothing
- Get involved! You can and MUST change this!